rewritable DVDs have been created. The standards

describe an ECC block structure appended with parity

codes for error correction as a data structure to be

recorded on an optical disk (information recording

5   medium). In existing DVDs, data having an ECC block

structure common to both read-only and rewritable

optical disks is recorded. Also, the application

standards that describe the recording format in the

application layer upon recording AV (Audio/Video)

10   information or stream information on existing DVDs have

been created.

In the physical standards, the minimum unit of

user information to be recorded on an optical disk

is 2048 bytes, and this recording unit is called

15   a physical sector. Data in the physical sector include

a data ID that records a sector number or the like,

an error detection code IED (Data ID Error Detection

code) for the data ID, user information, and an error

detection code EDC (Error Detection Code) for data in

20   the physical sector. As an error correction scheme

for improving the reliability of data recorded on

an optical disk, a "REED Solomon product code" scheme

is adopted, and an ECC block structure appended with

PI (inner-code parity) data and PO (outer-code parity)

25   data is formed. One ECC block consists of data for

16 sectors. The technique that pertains to the ECC

block structure is disclosed in Jpn. Pat. Appln. KOKAI

Publication No. 10-172243.

In the present specifications, data contents or
data structure including a data ID and parity data is
called "data", and user information (= Main data) to be
recorded is called "information". Also, data contents
5   or information contents directly recorded in a physical
sector on an optical disk are called "physical sector
data" (= physical sector data block) or "physical
sector information". One item of physical sector
10   information has a size of 2048 bytes.

The logical standards define the data structure
associated with user information to be recorded on
an optical disk when viewed from the host computer side
which is·connected to an interface of an information
15   reproduction or recording apparatus. The minimum
unit to be exchanged between the host computer and
information reproduction or recording apparatus is
defined as a logical sector, and in the present
specification, the contents of user information
20   corresponding to the logical sector are called logical
sector information. The logical sector information has
a size of 2048 bytes in correspondence with that of the
physical sector information.

The contents of the logical sector information
25   basically match those of the physical sector
information. However, since the physical layer defined
in the physical standard and the logical layer defined

in the logical standard are different layers, the contents of the physical sector information may be different from those of the logical sector information in practice. That is, the host computer and

5 information reproduction or recording apparatus exchange information using 2048-byte logical sector information as a minimum unit, and information obtained by processing this logical sector information may be recorded as physical sector information on an optical

10 disk.

The minimum unit of video object information or audio object information transferred between the host computer and information reproduction or recording apparatus is also 2048 bytes in correspondence with

15 the logical sector size. According to the application standards, video object information and audio object information are broken up into 2048 bytes, and are multiplexed in the format of a pack structure as a minimum unit upon being recorded on an optical disk.

20 That is, audio/video information to be recorded on a recording medium is segmented along the time axis, and video packs that store video object information and audio packs that store audio object information are distributed while being mixed. In this case, the video

25 or audio pack information itself corresponds to the contents of the logical sector information.

The minimum unit of recording stream information

is called an SOBU (Stream Object Unit), and one SOBU size is defined to be 32 logical sectors or 2 ECC blocks.

In existing DVDs, error correction can be made up to a maximum burst error length of 6 mm on an optical disk. In next-generation DVDs, the data bit length on an optical disk (recording medium) becomes small since the data recording density increases. Assume that the data bit length is proportional to the wavelength of light used in an optical head of the reproduction or recording/reproduction apparatus, and is inversely proportional to NA (Numerical Aperture). In this case, if the next-generation DVD has an optical wavelength of 405 nm and NA = 0.85 compared to the existing DVD having an optical wavelength of 650 nm and NA = 0.65, the error-correctable burst error length on an optical disk (recording medium) is considerably reduced to 2.9 mm.

$$6 \times (405 \div 650) \times (0.65 \div 0.85) = 2.9$$

Therefore, the next-generation DVD requires a technical means for assuring an error-correctable burst error length of 6 mm or more as in the current DVD.

When the correctable burst error length is greatly improved for the next-generation DVD while exploiting the REED Solomon product code technique as the ECC block structure, the following problems (1) to (2) are posed, and it is impossible to greatly improve the

correctable burst error length by only changing
the size of the REED Solomon product code of the
existing DVD.

(1) The maximum size of a REED Solomon product
code that corrects errors for respective unit bytes is
limited to 256 rows × 256 columns. In the existing
DVD, the maximum size is 208 rows × 182 columns.
The existing DVD has an optimal structure within the
limit range of 256 rows × 256 columns, and it is
difficult to greatly improve the correctable burst
error length by merely changing the size.

(2) The main data information encoding efficiency
cannot be greatly reduced compared to the existing DVD.
It is possible to improve the correctable burst error
length by increasing the PO size in an ECC block. But
when this is done, redundancy which depends on the PO
size increases and the main data information encoding
efficiently drops considerably. The existing DVD has
main data information encoding efficiency of 87% as
well as redundant data such as a data ID and the like
in the physical data. Hence, in the next-generation
DVD, an encoding efficiency of around 87% needs to be
assured.

(3) An appropriate physical data structure must
be guaranteed. As a method of greatly improving the
correctable burst error length and of assuring high
main data information encoding efficiency, a method of

largely increasing the PO size and reducing the PI size accordingly may be readily devised. However, in order to assure high-speed data access on an optical disk, the data ID must be arranged at the head in the

5 physical sector data, and an interleaved arrangement of PO data in respective physical sectors is required for this purpose. However, to attain this, it becomes difficult to change the PO size to an arbitrary value.

BRIEF SUMMARY OF THE INVENTION

10 It is an object of the present invention to provide an information recording medium, information recording apparatus, and information reproduction apparatus which can solve the aforementioned problems.

In order to solve the aforementioned problems and

15 to achieve the above object, an information recording medium, information recording apparatus, and information reproduction apparatus of the present invention have the following arrangements.

(1) An information recording medium of the

20 present invention comprises a management area where management information is recorded, and a plurality of physical sector areas used to record a plurality of physical sector data blocks, which are generated by combining some data contained in a plurality of ECC

25 blocks.

(2) An information recording apparatus of the present invention comprises generation section

configured to generating a plurality of ECC blocks, and

recording section configured to generating a plurality

of physical sector data blocks by combining some data

contained in the plurality of ECC blocks, and recording

5   the plurality of physical sector data blocks on a

plurality of physical sector areas on the information

recording medium.

     (3)   An information reproduction apparatus of the

present invention comprises read-out section configured

10   to reading out the plurality of physical sector data

blocks from the plurality of physical sector areas on

the information recording medium, and reproduction

section configured to reproducing data by generating

the plurality of ECC blocks from the plurality of

15   readout physical sector data blocks.

     Additional objects and advantages of the invention

will be set forth in the description which follows, and

in part will be obvious from the description, or may

be learned by practice of the invention. The objects

20   and advantages of the invention may be realized and

obtained by means of the instrumentalities and

combinations particularly pointed out hereinafter.

    BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

     The accompanying drawings, which are incorporated

25   in and constitute a part of the specification,

illustrate embodiments of the invention, and together

with the general description given above and the

detailed description of the embodiments given below,
serve to explain the principles of the invention.

5   FIG. 1 shows the data structure of physical sector
data generated from a plurality of ECC blocks, the
relationship between physical sector information and
logical sector information, and the like;

FIG. 2 shows the data structure of physical sector
data recorded on an information recording medium, and
the relationship between a plurality of physical sector
10   data and a plurality of (two) corresponding ECC blocks;

FIG. 3 shows the data structure of an ECC block
upon completion of row interleave when one sector data
consists of an odd number of rows;

FIG. 4 shows the data structure of physical sector
15   data generated from a single ECC block, the
relationship between physical sector information and
logical sector information, and the like;

FIG. 5 shows the data structure of physical sector
data recorded on an information recording medium, and
20   the relationship between a plurality of physical sector
data and a single corresponding ECC block;

FIG. 6 is a schematic block diagram showing the
arrangement of an information recording/reproduction
apparatus according to an embodiment of the present
25   invention;

FIG. 7 is a flowchart for explaining generation of
an ECC block and recording of physical sector data;

FIG. 8 shows the data structure of sector data when one sector data is formed of an odd number of rows;

FIG. 9 shows an example of re-arrangement of sector data when one sector data is formed of an odd number of rows;

FIG. 10 shows the data structure of sector data when one sector data is formed of an odd number of rows;

FIG. 11 shows a state wherein the sector block shown in FIG. 10 is horizontally segmented into two blocks, and outer and inner code parties are appended to the respective blocks;

FIG. 12 shows the data structure of physical sector data generated from an ECC block upon completion of row interleave shown in FIG. 3;

FIG. 13 shows a state wherein data contained in physical sector data undergoes zigzag recording;

FIG. 14 shows examples of the arrangement of an outer code (PO) in physical sector data;

FIG. 15 shows the data structure of an ECC block upon completion of row interleave when one sector data is formed of an even number of rows;

FIG. 16 shows the data structure of sector data when one sector data is formed of an even number of rows;

FIG. 17 shows an example of re-arrangement of

sector data when one sector data is formed of an even number of rows;

FIG. 18 shows the data structure of sector data when one sector data is formed of an even number of rows;

FIG. 19 shows a state wherein the sector block shown in FIG. 18 is horizontally segmented into two blocks, and inner and outer code parities are appended to the respective blocks; and

FIG. 20 shows the data structure of physical sector data generated from an ECC block upon completion of row interleave shown in FIG. 15.

DETAILED DESCRIPTION OF THE INVENTION

Preferred embodiments of the present invention will now be described with reference to the accompanying drawings.

Basic features of the present invention are as follows.

1) Physical sector data to be recorded on an optical disk is segmented into small pieces, and segmented data is sequentially arranged (interleaved) in n (n is a positive value equal to or larger than 2) ECC blocks.

2) It is devised to always arrange the data ID at the head position of each physical sector data before or after the interleave process. As a result, even when access is made for respective physical sectors,

address information can be quickly read out, and
high-speed access can be attained.

This embodiment exemplifies a case of "n = 2",
but the contents of the present invention are not
limited to this, and can be applied to a case of n = 3
or n = 4.

As a method of arranging one physical sector data
in a plurality of ECC blocks, the present invention has
proposed the following two methods.

Method 1: Physical sector information matches
logical sector information. One physical sector data
is segmented into rows including PI, the data for
respective rows are respectively assigned to n (n ≥ 2)
ECC blocks, and the total of the number of rows
including PI in one physical sector data and the number
of PO rows is an integer multiple of n.

Method 2: All pieces of information in one
logical sector are contained in a single ECC block.
Logical sector data contained in different ECC blocks
undergo an interleave process by alternately exchanging
rows of these blocks for respective rows, and a data
arrangement obtained as a result of that process is
recorded on an optical disk as physical sector data.

An outline of method 1 will be explained first
using FIGS. 1 and 2.

An optical disk (information recording medium 9)
has a physical sector area 9a and management area 9b.

The management area 9b records management information. Data recorded in the physical sector area 9a will be described below. AV information or stream information, which is transferred continuously, is broken up into small pieces, which are converted into pack structures appended with pack headers, and these packs are recorded on a plurality of physical sector areas 9a assured on the optical disk. More specifically, as shown in (a) of FIG. 1, video information and audio information are transferred while being arranged along the time axis in the form of video packs 1-0 to 1-3, and audio packs 2-0 and 2-1. Each of the video packs 1-0 to 1-3 and audio packs 2-0 and 2-1 has a data size of 2048 bytes, which matches the logical sector information size. The video packs 1-0 to 1-3 and audio packs 2-0 and 2-1 are abstractly handled as a plurality of pieces of logical sector information 3-1 to 3-31 in the logical layer, as shown in (b) of FIG. 1 (that is, examples of practical contents of the plurality of pieces of logical sector information 3-1 to 3-31 correspond to video packs 1-0 to 1-3 and audio packs 2-0 and 2-1). In method 1, since physical sector information and logical sector information match, these pieces of information are handled as a plurality of pieces of physical sector information 4-0 to 4-31, as shown in (c) of FIG. 1. As will be described in detail later, each item of physical sector information (4-0 to

4-31) has the following configuration. That is, 4-byte

PID information, 2-byte IED information, and a 10-byte

reserve field (the size in an existing DVD is 6 bytes)

are arranged at the head of each information, and a

5   4-byte EDC is arranged at the end of information (data

0-0-0 to data 0-0-5). After that, that sequence is

broken up into 188-byte data (each of the data 0-0-0 to

data 0-0-5), error correction PI (inner-code parity)

data (PI0-0-0 to PI0-0-5) is appended to every 188-byte

10   data, and this data is arranged in turn, as shown in

(d) of FIG. 1. In odd-numbered physical sector data

(physical sector data 5-0), PO (outer-code parity) data

(PO0) is arranged at the end of data to complete

physical sector data 6-0. The present invention is

15   characterized in that even-numbered physical sector

data (physical sector data 5-1) has a structure in

which PO data (PO1) is arranged in the second column

from the end of data, and data 1-1-5 and PI data

(PI1-1-5) are arranged at the end of the even-numbered

20   physical sector data (as will be described in detail

later). Physical sector data 5-0 to 5-31, which is

completed in this manner, is recorded on the physical

sector areas 9a on the optical disk (information

recording medium 9) in accordance with the order it is

25   arranged, as shown in (e) of FIG. 1. One physical

sector data item is recorded on one physical sector

area 9a.

As shown in (f) and (g) of FIG. 2, one physical
sector data 5-0 item is formed as a combination of
data in two different ECC blocks 8-0 and 8-1. More
specifically, data in the physical sector data 5-0 is
5   finely broken up into 200-byte data, and 188-byte data
0-0-0 and PI data 0-0-0 are arranged in the first row
in the ECC block 8-0. Next 188-byte data 0-1-0 and PI
0-1-0 in the physical sector data 5-0 are arranged in
the first row in the ECC block 8-1. Furthermore, the
10   next 188-byte data 0-0-1 and PI data 0-0-1 are arranged
in the second row in the ECC block 8-0. Of PO data in
the ECC block 8-1, the first 200 bytes are inserted in
the sixth row in the ECC block 8-1 as PO0. As a
result, data from data 0-0-0 to PO0 form the physical
15   sector data 5-0.

First data 1-0-0 and PI 1-0-0 that follow the
first data in the next physical sector data 5-1 are
arranged in the seventh row in the ECC block 8-0,
as shown in (f) of FIG. 2. Of PO data in the ECC block
20   8-0, the first 200-byte data is arranged as PO1 in the
12th row in the ECC block 8-0. In this way, PO data
(PO0, PO1) for respective rows (200 bytes) is arranged
at equal intervals for the respective physical sector
data 5-0 to 5-31, and the arrangement positions have
25   a difference of one physical sector data between a pair
of ECC blocks 8-0 and 8-1.

The detailed structure in the ECC blocks 8-0 and

8-1 shown in (f) and (g) of FIG. 2 will be explained
below with reference to FIG. 3.

FIG. 3 shows a combined state of two, right and
left (for each 200-byte column) ECC blocks. Each ECC

5   block has a structure in which 12-byte PI data is
appended every 188 bytes, and PO data for 16 rows is
appended. The PO data for 16 rows is decomposed into
row data item, each of which is interleaved and
inserted at every 12-row positions. The hatched

10   portion of 200-byte columns per row in FIG. 3 means
interleaved and inserted PO data.

The user information size assigned per sector is
2048 bytes as in an existing DVD, and information
having the same contents as those of logical sector

15   information recognized in the application layer is set
as each item of physical sector information (main
data). Four-byte data ID information, 2-byte IED
information, and a 10-byte reserve field (the size in
an existing DVD is 6 bytes) are arranged at the head of

20   2048 bytes of the physical sector information, and
4-byte EDC data is arranged at the end of the physical
sector information, thus forming all the data of
a physical sector.

Since one physical sector data is interleaved

25   across two small ECC blocks, an error-correctable burst
error length can be improved to nearly twice that of
the prior art. That is, one item of physical sector

data is broken up into 188-byte data items, each of which forms one row data by appending 12-byte PI data (since the existing PI size is 10 bytes, and is increased to 12 bytes, error correction performance per row can be improved), and this row data is alternately and sequentially arranged in right and left different ECC blocks. This embodiment is characterized in that data (data sector) in one physical sector has an odd number of rows, i.e., 11 rows, as shown in FIG. 3. Since the data sector is made up of an odd number of rows, the total number of rows can be even upon inserting one PO row in each physical sector, and the PO row can be properly inserted in two ECC blocks without forming an odd row.

PID information is always arranged at the head position (upper left corner position in FIG. 3) of each physical sector, and the PO insert positions are devised to allow efficient interleave insertion of PO data, as shown in FIG. 3. That is, PO data is arranged at the last row position of an even sector, and PO data is arranged at the second row position from the end of the sector in an odd sector. As a result, PO data is arranged in a single ECC block, and all physical sectors can have the same data size.

An outline of method 2 will be explained below using FIGS. 4 and 5.

As in method 1, AV information or stream

information is stored in the form of packs 1-0 to 1-3
and 2-0, as shown in (a) of FIG. 4, and the information
contents of the packs 1-0 to 1-3 and 2-0 correspond to
a plurality of pieces of logical sector information 3-0

5   to 3-16. For the plurality of pieces of logical sector
information 3-0 to 3-16 obtained at that time, ECC
blocks 7-0 and 7-1 are formed and PI information
(PI0-0-0 to PI16-1-1) and PO information (PO0-0, PO1-0)
are inserted by the same method as in the conventional

10   DVD standards ((c) of FIG. 4).

A large characteristic feature of the present
invention lies in that processes from the state in (b)
of FIG. 4 until (c) of FIG. 4, i.e., appending of data
ID information, IED information, a reserve field, and

15   EDC information and an insert process of PI information
(PI0-0-0 to PI16-1-1) and PO information (PO0-0, PO1-0)
are the same as in those of the conventional DVD (the
numbers of data byes are also the same). Therefore,
the structures in the ECC blocks 7-0 and 7-1 shown in

20   (f) and (g) of FIG. 5 perfectly match the conventional
DVD standards as well as the values of various numbers
of data byes. As a result, some of the ECC block
generation process (generation of PI and PO, and the
like) and error correction process in a reproduction

25   apparatus or recording/reproduction apparatus having
compatible functions between the existing DVD and
next-generation DVD can be used in common to those upon

using an existing DVD disk (medium), and the processing

routines and circuits of the reproduction apparatus or

recording/reproduction apparatus having compatible

functions between the existing DVD and next-generation

5   DVD can be simplified.

In order to improve an error-correctable burst

error length by interleaving data in physical sector

data 5-0 and 5-16 between the two ECC blocks 7-0 and

7-1, method 2 of the present invention executes an

10   exchange process between data rows and PI rows (data

0-0-1 and PI0-0-1, and data 16-1-1 and PI16-1-1)

located at the even-numbered row positions of logical

sector data at identical positions (having the same

row numbers) in the neighboring ECC blocks 7-0 and 7-1,

15   as shown in (d) of FIG. 4. Data ID information that

contains sector address information is arranged in the

first row in each logical sector data. Hence, when

only an exchange process between data rows and PI rows

at the even-numbered row positions is done, and an

20   exchange process between data rows and PI rows at

odd-numbered row positions is inhibited, arrangement of

the data ID information that contains sector address

information at the head positions in the physical

sector data 5-0 and 5-16 shown in (d) of FIG. 4 is

25   guaranteed. Each of the logical sector data items 6-0

and 6-16 always includes 12 rows (an even number of

rows) of data and PI rows. Hence, by exchanging data

and PI rows at the even-numbered row positions in the logical sector data items 6-0 and 6-16 according to the aforementioned rules, the positions of PO information (PO0-0, PO1-0) in the logical sector data items 6-0 and

5   6-1 and ECC blocks 7-0 and 7-1 remain unchanged without being exchanged. For this reason, the appending process of PO information and error correction process are facilitated. The physical sector data items 5-0 and 5-16 generated in this way are recorded on the

10   physical sector areas 9a on an optical disk (information recording medium 9) in accordance with the order data in the physical sector data items 5-0 and 5-16 are arranged. One physical sector data is recorded on one physical sector area 9a.

15   An example of an information recording/ reproduction apparatus (information recording apparatus or information reproduction apparatus) will be explained below using FIG. 6.

1.   Function of information recording/reproduction

20   apparatus

1-1. Basic function of information recording/reproduction apparatus

     An information recording/reproduction apparatus executes the following processes. That is,

25   •the apparatus records new information or rewrites (or erases) information at a predetermined position on the information recording medium 9 using a focused beam

spot; and

•the apparatus reproduces already recorded
information from a predetermined position on the
information recording medium 9 using a focused beam

5   spot.

1-1-1.   Basic function achieving means of information
recording/reproduction apparatus

As means for achieving the above basic functions,
the information recording/reproduction apparatus

10   executes the following processes.   That is,

•the apparatus traces a focused beam spot along
tracks (not shown) on the information recording
medium 9;

•the apparatus switches recording/reproduction/

15   erasure of information by changing the amount of light
of a focused beam spot with which the information
recording medium 9 is irradiated; and

•the apparatus converts an externally input
recording signal d into an optimal signal to record it

20   at high density and with a low error rate.

2.   Structure of mechanism portion and operation of
detection portion

2-1.   Basic structure of optical head 202 and signal
detection circuit

25   2-1-1.   Signal detection by optical head 202

The optical head 202 basically comprises
a semiconductor laser element as a light source,

a photodetector, and an objective lens. A laser beam
emitted by the semiconductor laser element is focused
on the information recording medium 9 via the objective
lens. The laser beam reflected by a light reflection

5   film or light reflective recording film of the
information recording medium 9 is photoelectrically
converted by the photodetector. A detection current
obtained by the photodetector undergoes current-voltage
conversion by an amplifier 213 to obtain a detection

10   signal. This detection signal is processed by
a focusing/tracking error detection circuit 217
or binarization circuit 212. In general, the
photodetector is divided into a plurality of
photodetection regions, which individually detect

15   changes in the amount of light with which the
respective photodetection regions are irradiated.
Respective detection signals undergo sum/difference
calculations by the focusing/tracking error detection
circuit 217, thus detecting focusing and tracking

20   errors. In this way, a change in the amount of light
reflected by the light reflection film or light
reflective recording film of the information recording
medium 9 is detected, thereby reproducing a signal on
the information recording medium 9.

25   2-1-2. Objective lens actuator structure

      The objective lens that focuses a laser beam
emitted by the semiconductor laser element on the

information recording medium 9 is movable in two
axis directions in accordance with an output current
from an objective lens actuator driving circuit 218.
The objective lens moves:

5 •in a direction perpendicular to the information
recording medium 9 to correct focusing errors; and

•in the radial direction of the information
recording medium 9 to correct tracking errors.

Such an objective lens moving mechanism is called
10 an objective lens actuator (not shown).

2-2. Rotation control system of information recording
medium 9

The information recording medium 9 is mounted on
a rotary table 221 which is rotated by the driving
15 force of a spindle motor 204. The rotational speed of
the information recording medium 9 is detected based on
a reproduction signal obtained from the information
recording medium 9. That is, the detection signal
(analog signal) output from the amplifier 213 is
20 converted into a digital signal by the binarization
circuit 212, and a PLL circuit 211 generates a constant
period signal (reference clock signal) based on that
digital signal. An information recording medium
rotational speed detection circuit 214 detects the
25 rotational speed of the information recording medium 9
using this signal, and outputs the detection value.

A correspondence table of the information

recording medium rotational speed which corresponds to the radial position where data is reproduced or recorded/erased on the information recording medium 9 is pre-stored in a semiconductor memory 219. When a reproduction position or recording/erasure position is determined, a controller 220 sets a target rotational speed of the information recording medium 9 by looking up information recorded in the semiconductor memory 219, and sends that value to a spindle motor driving circuit 215.

The spindle motor driving circuit 215 calculates the difference between this target rotational speed and the output signal (current rotational speed) of the information recording medium rotational speed detection circuit 214, and supplies the driving current corresponding to that difference to the spindle motor 204, thus controlling the rotational speed of the spindle motor 204 to be constant. The output signal from the information recording medium rotational speed detection circuit 214 is a pulse signal having a frequency corresponding to the rotational speed of the information recording medium 9, and the spindle motor driving circuit 215 controls both the frequency and pulse phase of this signal.

2-3. Optical head moving mechanism

To move the optical head 202 in the radial direction of the information recording medium 9,

an optical head moving mechanism (feed motor) 203 is provided.

3. Functions of respective control circuits

3-1. Focused beam spot trace control

In order to perform focusing or tracking error correction, a circuit for supplying a driving current to the objective lens actuator in the optical head 202 in accordance with the output signal (detection signal) from the focusing/tracking error detection circuit 217 is the objective lens actuator driving circuit 218. This circuit 218 includes a phase compensation circuit for improving characteristics in correspondence with the frequency characteristics of the objective lens actuator to attain quick response of objective lens movement up to the high-frequency range.

In response to a command from the controller 220, the objective lens actuator driving circuit 218 executes:

•an ON/OFF process of focusing/tracking error correction operation (focus/track loop);

•a process for moving the objective lens at low speed in a direction (focus direction) perpendicular to the information recording medium 9 (executed when focus/track loop is OFF); and

•a process for moving a focused beam spot to a neighboring track by slightly moving in the radial direction (direction to cross tracks) of the

information recording medium 9 using a kick pulse.

4. Various operations associated with control system
of mechanism portion

4-1. Startup control

When the information recording medium 9 is mounted
on the rotary table 221 and startup control is started,
the processes are executed in accordance with the
following sequence.

1) The controller 220 sends a target rotational
speed to the spindle motor driving circuit 215, which
supplies a driving current to the spindle motor 204,
thus starting rotation of the spindle motor 204.

2) At the same time, the controller 220 issues
a command (execution command) to the feed motor driving
circuit 216, which supplies a driving current to the
optical head driving mechanism (feed motor) 203, thus
moving the optical head 202 to the innermost peripheral
position of the information recording medium 9. It is
confirmed if the optical head 202 has reached an inner
peripheral portion beyond the information recording
region on the information recording medium 9.

3) When the spindle motor 204 has reached the
target rotational speed, that status (status report) is
output to the controller 220.

4) A semiconductor laser driving circuit 205
supplies a current to the semiconductor laser element
in the optical head 202 in correspondence with

a reproduction light amount signal sent from the controller 220 to a recording/reproduction/erasure control waveform generation circuit 206, thus starting laser emission.

Note that an optimal irradiation light amount upon reproduction varies depending on the types of information recording media 9. Upon startup, the lowest irradiation light amount value of those values is set.

5) The objective lens actuator driving circuit 218 controls to move the objective lens (not shown) in the optical head 202 to a position farthest from the information recording medium 9, and make the objective lens slowly approach the information recording medium 9 in accordance with a command from the controller 220.

6) At the same time, the focusing/tracking error detection circuit 217 monitors a focusing error amount, and outputs status to the controller 220 when the objective lens has approached an in-focus position.

7) Upon receiving that status, the controller 220 issues a command to the objective lens actuator driving circuit 218 to enable the focus loop.

8) The controller 220 issues a command to the feed motor driving circuit 216 while the focus loop is ON to slowly move the optical head 202 toward the outer periphery of the information recording medium 9.

9) At the same time, a reproduction signal from

the optical head 202 is monitored. When the optical head 202 has reached the recording region on the information recording medium 9, the controller 220 stops movement of the optical head 202, and issues a command to the objective lens actuator driving circuit 218 to enable the track loop.

10) An "optimal light amount upon reproduction" and "optimal light amount upon recording/erasure" recorded on the inner peripheral portion of the information recording medium 9 are reproduced, and are recorded in the semiconductor memory 219 via the controller 220.

11) Furthermore, the controller 220 sends a signal corresponding to that "optimal light amount upon reproduction" to the recording/reproduction/erasure control waveform generation circuit 206, thus re-setting the emission amount of the semiconductor laser element upon reproduction.

12) The emission amount of the semiconductor laser element upon recording/erasure is set in correspondence with the "optimal light amount upon recording/erasure" recorded on the information recording medium 9.

4-2. Access control

4-2-1. Reproduction of access destination information on information recording medium 9

Information that indicates the locations and

contents of information recorded on the information

recording medium 9 varies depending on the types of

information recording medium 9, and is generally

recorded in directory management regions, navigation

5   packs, or the like in the information recording medium

9. Note that the directory management regions are

recorded together in the inner or outer peripheral

region of the information recording medium 9. On the

other hand, the navigation pack is contained in a VOBS

10   (Video Object Set) complying with the data structure of

a PS (Program Stream) of MPEG2, and records information

indicating the location of the next video data.

When specific information is to be reproduced or

recorded/erased, information in the above-mentioned

15   region is reproduced, and an access destination is

determined based on the reproduced information.

4-2-2. Coarse access control

The controller 220 calculates the radial position

of the access destination, and detects the distance

20   between that position and the current position of the

optical head 202. As for the moving distance of the

optical head 202, velocity curve information that

allows the head to reach the target position within a

shortest period of time is stored in advance in the

25   semiconductor memory 219. The controller 220 reads

that information, and controls movement of the optical

head 202 by the following method in accordance with the

velocity curve. The controller 220 issues a command to
the objective lens actuator driving circuit 218 to
disable the track loop, and then controls the feed
motor driving circuit 216 to start movement of the
5   optical head 202. When the focused beam spot has
crossed a track on the information recording medium 9,
the focusing/tracking error detection circuit 217
generates a tracking error detection signal. Using
this tracking error detection signal, the relative
10   velocity of the focused beam spot with respect to
the information recording medium 9 can be detected.
The feed motor driving circuit 216 calculates the
difference between the relative velocity of the focused
beam spot obtained from the focusing/tracking error
15   detection circuit 217, and target velocity information
sent from the controller 220, and feeds back that
result to the driving current to be supplied to the
optical head driving mechanism (feed motor) 203, thus
moving the optical head 202. As described in "optical
20   head moving mechanism", a frictional force always acts
between a guide shaft and bushing or bearing. When the
optical head 202 moves at high speed, dynamic friction
acts. However, since the moving velocity of the
optical head 202 is low at the beginning of movement
25   and immediately before stop, static friction acts.
At that time, since the relative frictional force
increases, the amplification factor (gain) of a current

to be supplied to the optical head driving mechanism
(feed motor) 203 is increased in response to a command
from the controller 220 (especially, immediately before
stop).

5   4-2-3. Fine access control

         When the optical head 202 has reached the target
position, the controller 220 issues a command to the
objective lens actuator driving circuit 218 to enable
the track loop. The focused beam spot reproduces an

10   address or track number of that portion while tracing
along a track on the information recording medium 9.
The current focused beam spot position is detected from
that address or track number, and the controller 220
calculates the number of error tracks from the reached

15   target position and informs the objective lens actuator
driving circuit 218 of the number of tracks the focused
beam spot is required to move. When the objective lens
actuator driving circuit 218 generates a pair of kick
pulses, the objective lens slightly moves in the radial

20   direction of the information recording medium 9, thus
moving the focused beam spot to a neighboring track.
In the objective lens actuator driving circuit 218,
the track loop is temporarily disabled, and after kick
pulses are generated a given number of times corre-

25   sponding to the information from the controller 220,
the track loop is enabled again. Upon completion of
fine access, the controller 220 reproduces information

(address or track number) at the position where the
focused beam spot is tracing, and confirms if it has
accessed a target track.

4-3. Continuous recording/reproduction/erasure control

As shown in FIG. 6, a tracking error detection
signal output from the focusing/tracking error
detection circuit 217 is input to the feed motor
driving circuit 216. "Upon startup control" and "upon
access control" mentioned above, the controller 220
controls the feed motor driving circuit 216 not to use
the tracking error detection signal. After it is
confirmed that the focused beam spot has reached the
target track by access, some components of the tracking
error detection signal are supplied as a driving
current to the optical head driving mechanism (feed
motor) 203 in response to a command from the controller
220. This control continues during the period in which
a reproduction or recording/erasure process is done
continuously. The information recording medium 9 is
mounted so that its central position has a slight
eccentricity from that of the rotary table 221. When
some components of the tracking error detection signal
are supplied as a driving current, the entire optical
head 202 slightly moves in correspondence with the
eccentricity. When the reproduction or recording/
erasure process is continuously done for a long period
of time, the focused beam spot position gradually moves

toward the outer or inner periphery. When some
components of the tracking error detection signal are
supplied as a driving current to the optical head
moving mechanism (feed motor) 203, the optical head 202
gradually moves toward the outer or inner periphery
in correspondence with that current. In this manner,
the load on tracking error correction of the objective
lens actuator is reduced, thus attaining a stable track
loop.

4-4. End control

When a series of processes are complete and the
operation is to be ended, the process is done in
accordance with the following sequence. That is,

1) the controller 220 issues a command to the
objective lens actuator driving circuit 218 to disable
the track loop;

2) the controller 220 issues a command to the
objective lens actuator driving circuit 218 to disable
the focus loop;

3) the controller 220 issues a command to the
recording/reproduction/erasure control waveform
generation circuit 206 to stop emission of the
semiconductor laser element; and

4) the controller 220 informs the spindle motor
driving circuit 215 of zero reference rotational speed.

5. Flow of recording signal/reproduction signal to
information recording medium

5-1. Signal format recorded on information recording medium 9

In order to meet requirements:

•of correcting recording information errors caused by defects on the information recording medium 9;

•of simplifying a reproduction processing circuit by setting zero DC components of a reproduction signal; and

•of recording information at highest possible density on the information recording medium 9 for a signal to be recorded on the information recording medium 9, the information recording/reproduction apparatus (physical system block) performs "addition of an error correction function" and "signal conversion of recording information (signal modulation/ demodulation)", as shown in FIG. 6.

5-2. Flow of signal upon recording

5-2-1. ECC (Error Correction Code) appending process

Information to be recorded on the information recording medium 9 is input to a data input/output interface 222 as recording signal d in the form of a raw signal. This recording signal d is directly recorded in the semiconductor memory 219, and then undergoes an ECC appending process in an ECC encoding circuit 208, as will be described later.

Upon completion of appending of inner-code PI and outer-code PO, the ECC encoding circuit 208 reads data

for one sector from the semiconductor memory 219, and transfers the read data to a modulation circuit 207.

5-2-2. Signal modulation

In order to make a DC component (DSV: Digital Sum Value) of a reproduction signal approach zero, and to record information on the information recording medium 9 at high density, signal modulation as conversion of a signal format is done in the modulation circuit 207. The modulation circuit 207 and a demodulation circuit 210 include a conversion table indicating the relationship between a source signal and modulated signal. The signal transferred from the ECC encoding circuit 208 is segmented into data each consisting of a plurality of bits in accordance with a modulation scheme, and the segmented data is converted into other signals (codes) by looking up the conversion table. For example, when 8/16 modulation (RLL (2, 10) code) is used as the modulation scheme, two different types of conversion tables are present, and the conversion table to be looked up is switched as needed to make the DC component (DSV) after modulation approach zero.

5-3. Flow of signal upon reproduction

5-3-1. Binarization/PLL circuit

As described in "signal detection by optical head 202", a change in the amount of light reflected by the light reflection film or light reflective recording film of the information recording medium 9 is detected

to reproduce a signal on the information recording medium 9. A signal obtained by the amplifier 213 has an analog waveform. The binarization circuit 212 converts that signal into a binary digital signal consisting of "1" and "0" using a comparator.

From the reproduction signal obtained by the binarization circuit, the PLL circuit 211 extracts a reference signal upon reproducing information. The PLL circuit 211 incorporates a variable frequency oscillator. The frequency and phase of a pulse signal (reference clock) output from the oscillator are compared with those of the output signal from the binarization circuit 212, and the comparison results are fed back to the oscillator output.

5-3-2. Signal demodulation

The demodulation circuit 210 incorporates a conversion table indicating the relationship between modulated and demodulated signals. A modulated signal is restored to an original signal by looking up the conversion table in synchronism with the reference clock obtained by the PLL circuit 211. The restored (demodulated) signal is recorded in the semiconductor memory 219.

5-3-3. Error correction process

An error correction circuit 209 detects any errors of a signal saved in the semiconductor memory 219 using inner-code PI and outer-code PO, and sets pointer flags

of error positions.

After that, the error correction circuit 209
corrects a signal at the error positions in accordance
with the error pointer flags while reading out the
signal from the semiconductor memory 219, removes
inner-code PI and outer-code PO, and transfers the
signal to the data input/output interface 222.

A signal sent from the ECC encoding circuit 208
is output as reproduction signal c from the data
input/output interface 222.

This concludes the detailed description of FIG. 6
is to end.

The format process sequence executed in the
apparatus shown in FIG. 6 will be explained below using
the flowchart shown in FIG. 7. The format process is
implemented by the ECC encoding circuit 208 and
controller 220. FIG. 7 shows the sequence of the data
conversion process (format) based on method 1 shown in
FIGS. 1 to 3.

Step 1) A plurality of pieces of physical sector
information 4-0 to 4-31 are set (segmented into main
data in units of 2048 bytes) in correspondence with
the size of a plurality of pieces of logical sector
information 3-0 to 3-31. User data to be recorded is
handled in units of 2048 bytes.

Step 2) 2068-byte sector data is generated
from 2048-byte main data, 16-byte auxiliary data, and

a 4-byte error detection code (EDC).

As shown in FIG. 8, the 16-byte auxiliary data contains 4-byte data ID data (PID), a 2-byte error detection code (IED) for the data ID, and 10-byte reserve data (RSV). The PID records a sector number used to identify a data sector, and sector information used to identify the contents of the data sector. The IED is used to detect any errors generated in the PID portion. The RSV is used to record other kinds of auxiliary information (e.g., copyright management information). The EDC is used to detect any errors generated in 2064-byte main data and auxiliary data. The data sectors are arranged in a 188 (columns) × 11 (rows) matrix, as shown in FIG. 8.

Step 3) Scramble data is added to 2048-byte main data of each sector data.

Step 4) The rows of the sector data shown in FIG. 8 are re-arranged depending on whether the sector number is even or odd, as shown in FIG. 9. Numerals in FIG. 9 indicate row numbers in the sector data. Also, as shown in FIG. 9, re-arrangement types α and β are available.

Step 5) A sector block is generated by vertically stacking 32 continuous data sectors, which are re-arranged depending on their sector numbers. The data sectors which are vertically stacked are arranged in a 376 (columns) × 176 (rows) matrix, as shown in FIG. 10.

Step 6)   The sector block is horizontally
segmented into two blocks to encode error correction
codes.   The 188 (columns) × 176 (rows) blocks after
segmentation undergo encoding in the column direction
5   to generate outer-code parity (PO) data for 16 rows.
The outer code uses a REED Solomon code of RS(192, 176,
17).   Subsequently, inner-code encoding is done in the
row direction to generate inner-code parity data (PI)
for 12 columns.   The inner code uses a REED Solomon
10   code of RS(200, 188, 13).   ECC blocks containing parity
data generated based on the inner and outer codes are
as shown in FIG. 11.

Step 7)   The ECC blocks undergo row interleave to
distribute 16 right and left rows of PO data into the
15   blocks.   Thirty-two rows (= 16 × 2) of PO data are
distributed row by row to sectors.   At this time, PO
rows of the left block are inserted after the lowermost
row of only five odd rows, and PO rows of the right
block are inserted after the lowermost row of only five
20   even rows.   FIG. 3 shows the ECC blocks after row
interleave.

Step 8)   Physical sector data is completed.
FIG. 12 shows the completed physical sector data
(= physical sector data blocks).

25   Step 9)   A zigzag recording matrix is set.

Step 10)   A modulation process is executed.
If a bit sequence of data to be recorded is directly

recorded on the medium, the characteristic feature
of the recording data sequence does not match the
recording characteristics of the medium, and efficient
recording cannot be done. In consideration of the

5   recording characteristics of the medium, a data pattern
is converted according to a predetermined conversion
rule. For example, the modulation scheme includes
an 8/16 modulation scheme for converting 1-byte data
into a 16-bit pattern, an 8/12 modulation scheme for

10   converting 1-byte data into a 1.5-byte pattern, a 12/18
modulation scheme for converting 12-bit data into an
18-bit pattern, and the like. Any one of these schemes
comprises a plurality of conversion tables and a logic
circuit for selecting the conversion table.

15   Especially, since the 12/18 modulation scheme
that converts 1.5-byte data has a characteristic of
expanding an error at one position to 1.5 bytes, it
is effective for the process executed in step 9 to
distribute errors upon reproduction.

20   Via steps 1 to 10, zigzag recording according to
the setup in step 9 is done. Zigzag recording will
be described in detail below. The contents of the
physical sector data structure shown in FIG. 12 are
segmented further finely. Assume that the fine

25   segmentation size is 1 byte, as shown in, e.g.,
FIG. 13. However, the present invention is not limited
to such specific segmentation unit length, and for

example, a 2- or 4-byte unit may be used. Data are selected and extracted across rows for respective segmentation units, and are recorded on the physical sector area 9a on the optical disk (information recording medium 9) in accordance with the order they are selected and extracted. One physical sector data is recorded on one physical sector area 9a.

For example, as shown in FIG. 13, two upper and lower rows are paired, data in these upper and lower rows is extracted alternately (in a zigzag pattern) for respective segmentation units, and upon completion of one cycle of data extraction in a single column, unextracted data in these pairs of rows is alternately fetched and recorded on the physical sector area 9a on the optical disk (information recording medium 9).

In this case, the format method for method 1 has been mainly explained. However, the process in step 9 is also effective for method 2. Especially, in method 2, since neighboring rows belong to the different ECC blocks 7-0 and 7-1, as shown in FIGS. 4 and 5, if data is arranged across rows, data distribution across the ECC blocks 7-0 and 7-1 is attained. Hence, error distribution can be attained at a level finer than the interleave process across the ECC blocks 7-0 and 7-1 for respective rows.

In FIG. 13, data is extracted in a zigzag pattern from a pair of rows. However, the present invention is

not limited to this. For example, data may be sequentially extracted across three rows, or data may be selected and extracted for respective segmentation units across all six rows, and may be re-arranged and

5   recorded on the physical sector area 9a on the optical disk (information recording medium 9).

As another recording method, data of different ECC blocks every rows may be alternately recorded for several bytes, e.g., 1 byte.

10   Also, recording of data for one row in an order it is arranged does not disturb the basic feature of the present invention.

Furthermore, a physical sector information portion may be re-arranged in any stage before step 6 so that

15   auxiliary information containing at least an ID continuously appears on a recorded data sequence in accordance with the data recording order in step 9.

The information recording medium on which physical sector data is recorded in this way is reproduced by

20   the information recording/reproduction apparatus shown in FIG. 6. That is, physical sector data is read out from a predetermined number of (32) physical sector areas 9a, n (2) ECC blocks are generated from the readout physical sector data, sector data is generated

25   and reproduced from the ECC blocks via an error correction process. The physical sector data is read out by the optical head. The sector data is reproduced

by the error correction circuit 209.

More specifically, by utilizing a process opposite
to that for generating a predetermined number of
physical sector data from n ECC blocks, n ECC blocks

5   are generated from the predetermined number of physical
sector data items read out from the predetermined
number of physical sector areas 9a. That is, two ECC
blocks shown in FIG. 3 are generated from the physical
sector data shown in FIG. 12. Subsequently, by

10   utilizing a process opposite to that for generating ECC
blocks after row interleave from those before row
interleave, the n generated ECC blocks are restored to
n ECC blocks before row interleave. That is, n (2) ECC
blocks shown in FIG. 3 are restored to n ECC blocks

15   shown in FIG. 11. At this time, an error correction
process is executed using outer- and inner-code parity
data appended to the ECC blocks. By utilizing a
process opposite to that for generating ECC blocks from
sector blocks, the ECC blocks are restored to sector

20   blocks. That is, outer- and inner-code parity data
is removed from the ECC blocks shown in FIG. 11 to
generate sector blocks shown in FIG. 10. Then, by
utilizing a process opposite to that for generating
sector blocks from sector data, sector data is

25   generated from the sector blocks. That is, sector data
shown in FIG. 9 is generated from the sector blocks
shown in FIG. 10. Since the generated sector data is

in the re-arranged state, it is restored to an original
arrangement upon reproduction.

Note that the physical sector data has a data
structure in which the data ID is arranged at the head

5   of the data, and a data line formed by only a portion
of outer-code parity data is arranged as the final
line. Hence, the information recording/reproduction
apparatus shown in FIG. 6 can reproduce the data ID by
reading out the head data of the physical sector data.

10 Each physical sector area records data alternately
extracted from different data lines in the physical
sector data in turn (zigzag recording). Hence, the
information recording/reproduction apparatus reproduces
each physical sector area under the condition that data

15 alternately extracted from different data lines is
recorded.

FIG. 14 shows another embodiment of the data
structure in physical sector data in method 1.
As shown in FIG. 14, data structures (A) to (C) are

20 available, and are application examples which can be
basically generated via the aforementioned steps.

The format process for case (C) in FIG. 14, i.e.,
a case wherein one sector is formed of an even number
of rows, will be explained below using the flowchart

25 shown in FIG. 7 again.

The process to be described below is executed in
the ECC encoding circuit 208 shown in FIG. 6, and

detailed control is made by the controller 220.

Step 1) A plurality of pieces of physical sector information 4-0 to 4-31 are set (segmented into main data in units of 2048 bytes) in correspondence with the size of a plurality of pieces of logical sector information 3-0 to 3-31. User data to be recorded is handled in units of 2048 bytes.

Step 2) 2064-byte sector data is generated from 2048-byte main data, 12-byte auxiliary data, and a 4-byte error detection code (EDC). As shown in FIG. 16, the 12-byte auxiliary data contains 4-byte data ID data (PID), a 2-byte error detection code (IED) for the data ID, and 6-byte reserve data (RSV). The sector data is arranged in a 172 (columns) × 12 (rows) matrix, as shown in FIG. 16.

Step 3) Scramble data is added to 2048-byte main data of each sector data.

Step 4) The rows of the sector data shown in FIG. 16 are re-arranged depending on whether the sector number is even or odd, as shown in FIG. 17. Numerals in FIG. 17 indicate row numbers in the sector data. Also, as shown in FIG. 17, re-arrangement types α and β are available.

Step 5) A sector block is generated by vertically stacking 32 continuous data sectors, which are re-arranged depending on their sector numbers. The sectors are which are vertically stacked are

arranged in a 344 (columns) × 192 (rows) matrix, as shown in FIG. 18.

Step 6)   The sector block is horizontally segmented into two blocks to encode error correction codes.   The 172 (columns) × 192 (rows) blocks after segmentation undergo encoding in the column direction to generate outer-code parity (PO) data for 16 rows. The outer code uses a REED Solomon code of RS(208, 192, 17).   Subsequently, inner-code encoding is done in the row direction to generate inner-code parity data (PI) for 12 columns.   The inner code uses a REED Solomon code of RS(184, 172, 13).   ECC blocks containing parity data generated based on the inner and outer codes are as shown in FIG. 19.

Step 7)   The ECC blocks undergo row interleave to distribute 16 right and left rows of PO data into the blocks.   Thirty-two rows (= 16 × 2) of PO data are distributed row by row to sectors.   As the distribution destinations of PO data, this data is inserted after the lowermost row of even sectors in the left block, and after the lowermost row of odd sectors in the right block.   FIG. 15 shows the ECC blocks after row interleave.

Step 8)   Physical sector data is completed. FIG. 20 shows the completed physical sector data.

Step 9)   In this case, the setup of the zigzag recording matrix is omitted.   This is because two

different physical sector data items are involved at
the lowermost row of the physical sector data (see

FIG. 15). If the zigzag recording matrix is set in

this case, two different physical sectors are mixed

5   together in one physical sector area.

Step 10) A modulation process is executed.
If a bit sequence of data to be recorded is directly

recorded on the medium, the characteristic feature of

the recording data sequence does not match the

10   recording characteristics of the medium, and efficient

recording cannot be done. In consideration of the

recording characteristics of the medium, a data pattern

is converted according to a predetermined conversion

rule.

15   The information recording medium on which physical

sector data is recorded in this way is reproduced by

the information recording/reproduction apparatus shown

in FIG. 6. That is, physical sector data is read out

from a predetermined number of (32) physical sector

20   areas 9a, n (2) ECC blocks are generated from the

readout physical sector data, sector data is generated

and reproduced from the ECC blocks via an error

correction process.

More specifically, by utilizing a process opposite

25   to that for generating a predetermined number of

physical sector data items from n ECC blocks, n ECC

blocks are generated from the predetermined number

of physical sector data items read out from the
predetermined number of physical sector areas 9a.
That is, two ECC blocks shown in FIG. 15 are generated
from the physical sector data shown in FIG. 20.

5   Subsequently, by utilizing a process opposite to that
for generating ECC blocks after row interleave from
those before row interleave, the n generated ECC blocks
are restored to n ECC blocks before row interleave.
That is, n (2) ECC blocks shown in FIG. 15 are restored

10   to n ECC blocks shown in FIG. 19. At this time,
an error correction process is executed using outer-
and inner-code parity data appended to the ECC blocks.
By utilizing a process opposite to that for generating
ECC blocks from sector blocks, the ECC blocks are

15   restored to sector blocks. That is, outer- and inner-
code parity data is removed from the ECC blocks shown
in FIG. 19 to generate sector blocks shown in FIG. 18.
Then, by utilizing a process opposite to that for
generating sector blocks from sector data, sector data

20   is generated from the sector blocks. That is, sector
data shown in FIG. 17 is generated from the sector
blocks shown in FIG. 18. Since the generated sector
data is in the re-arranged state, it is restored to
an original arrangement upon reproduction.

25   Note that the physical sector data has a data
structure in which the data ID is arranged at the head
of the data, and a data line formed by only a portion

of outer-code parity data is arranged as the final line. Hence, the information recording/reproduction apparatus shown in FIG. 6 can reproduce the data ID by reading out the head data of the physical sector data.

Points of the present invention described above will be summarized below.

(1) One physical sector is segmented into rows including PI, and row data is assigned to a plurality of ECC blocks.

(2) In the data arrangement of all physical sectors, the data ID is always arranged at the head position. This structure matches the data arrangement in physical sectors of the existing DVD. In this manner, since the data arrangement in an important portion in each physical sector matches that of the existing DVD standards, the access control and sector address detection/confirmation processes in a reproduction apparatus or recording/reproduction apparatus having compatible functions between the existing DVD and next-generation DVD can be commonly used, thus simplifying control in the apparatus.

(3) All physical sectors have equal sizes.

(4) "2 ECC blocks = 32 physical sectors" is set as a basic unit in correspondence with the SOBU size, and all data in 32 physical sectors is assigned to two ECC blocks in the basic unit.

(5) Physical sector information matches logical

sector information. The contents of one physical

sector data are segmented into rows each including PI

data, row data is assigned in turn to n (n ≥ 2) ECC

blocks, and the total of the number of rows each

5   including PI in one physical sector data and the number

of PO rows is an integer multiple of n.

(6)   All pieces of information in one logical

sector are contained in data in a single ECC block.

(7)   Data in rows assigned to different ECC blocks

10   in a single physical sector is selected in turn and is

recorded on the optical disk.

The arrangements and effects of the information

recording medium, information recording apparatus, and

information reproduction apparatus of the present

15   invention will be described in detail below.

<1>   First to fifth data units are defined as

follows.

A minimum unit recorded on a medium from which

information can be reproduced or on which information

20   can be recorded is defined as a first data unit

(physical sector). A second data unit (a group of n

ECC blocks) including the first data unit is defined.

A third data unit (ECC block data) which is included in

the second data unit and forms an ECC block that forms

25   a REED Solomon product code is defined. The second

data unit includes n (n is a positive number equal to

or greater than 2) independent third data units having

equal data sizes. A fourth data unit which is included in the third data unit and forms one row as a data arrangement appended with PI (inner-code parity) data is defined. A fifth data unit (PO for one row) which forms PO (outer-code parity) data in the third data unit and is segmented to be equal to the size (row size) of the fourth data unit is defined.

The first data unit is formed by a set of fourth and fifth data units, the total of the number of fourth data units (the number of rows containing PI) and the number of fifth data units (the number of PO rows) is an integer multiple of n, and a data structure in which data of the fourth data units is always arranged at specific positions in the first data unit and a data ID containing address information is always arranged at a specific position in the fourth data unit is generated.

The information recording medium of the present invention comprises a physical sector area on which data with the aforementioned data structure is recorded. The information recording apparatus and method of the present invention generate data with such a data structure, and record the data with the data structure on the information recording medium. Furthermore, the information reproduction apparatus and method of the present invention reproduce the information recording medium on which the data with such a data structure is recorded.

The relationship between the aforementioned data units is as follows.

second data unit ⊃ first data unit ⊃ fourth data unit

(n × ECC block) (physical sector) (row including PI)

second data unit ⊃ Third data unit ⊃ fourth data unit

(n × ECC block) (ECC block) (row including PI)

second data unit ⊃ Third data unit ⊃ fifth data unit

(n × ECC block) (ECC block) (row including PO)

The points of the present invention are as follows.

1)   Data in one physical sector is segmented into rows, and row data is assigned to a plurality of ECC blocks.

2)   A data ID is arranged at the head position in the physical sector, and PO data for one row is arranged in a row other than the first row.

3)   The sum of the number of rows including PI and the number of PO rows is an integer multiple of the number of corresponding ECC blocks.

The effects of the present invention are as follows.

1)   Since the physical sector information size is the same as that in the existing DVD (2048 bytes), full compatibility between the standard contents of the logical layer and application layer of the existing DVD can be assured, and existing DVD data can be effectively used by exchange and mixed storage of data

recorded on existing DVDs is possible.

2) Since n third data units are included in the second data unit, and physical sector data (first data unit) is interleaved and arranged in different ECC blocks (third data units) for respective rows (fourth data units), an error-correctable burst error length can be improved approximately to n times. Hence, the present invention can relatively easily improve the error-correctable burst error length greatly without considerably lowering the main data information encoding efficiency compared to the existing DVD standards.

3) The effect of a perfect product code formed by appending inner-code (PI) data in the horizontal direction and outer-code (PO) data in the vertical direction is as follows.

●Since inner-code correction for outer-code parity data and outer-code correction for inner-code parity data can be done, correction performance can be improved by repeating correction using inner and outer code data for all recorded data.

●In combination with recording interleave, both distribution of successive errors to inner-code data and perfection of a product code that allows repetitive correction can be achieved.

●Upon examining a method of "appending inner-code data obliquely for the purpose of distributing

successive errors" for the purpose of comparison so as to obtain the effect of "the perfect product code formed by appending inner-code (PI) data in the horizontal direction and outer-code (PO) data in the vertical direction", perfection of the product code is impaired, and correction performance cannot be improved by repeating correction using inner- and outer-code data in such a case.

4) Except for interleave between a plurality of ECC blocks, data correspondence in the ECC blocks and physical sector data matches that of the existing DVD standards:

•correspondence between physical sector data and ECC block data for respective rows including PI; and

•interleaved arrangement of PO in ECC blocks to respective physical sectors.

In this manner, some of the ECC block generation process (generation of PI and PO, and the like) and error correction processes in a reproduction apparatus or recording/reproduction apparatus having compatible functions between the existing DVD and next-generation DVD can be used common to those used upon using an existing DVD disk (medium), and the processing routines and circuits of the reproduction apparatus or recording/reproduction apparatus having compatible functions between existing DVDs and next-generation DVD can be simplified.

5) Since a data ID is arranged at the head of physical sector data as in the existing DVD standards, the access control and sector address detection/ confirmation processes in a reproduction apparatus or recording/reproduction apparatus having compatible functions between existing DVDs and next-generation DVDs can be commonly used, thus simplifying control in the apparatus.

6) Since the total of the number of rows including PI (the number of fourth data units) and the number of PO rows (the number of fifth data units) included in the physical sector (first data unit) is an integer multiple of n, all data contained in one physical sector can be uniformly distributed (interleaved and arranged) in all corresponding ECC blocks. Since all data can be evenly arranged in the ECC blocks, an interleave process to the ECC blocks can be facilitated, and equal error-correctable burst error lengths can be obtained independently of the positions on the optical disk, thus preventing adverse influences of burst errors on reproduced information. That is, since an interleave process is made to alternately record n product code data items on respective rows, uniform burst error correction performance can be obtained. Hence, there is no locally weak burst error correction performance portion. Even when an interleave process for alternately arranging data is

done, all the sectors can have equal sector lengths.

7) All the physical sectors have the same number of PO data items to have equal physical sector sizes, and the following merits can be obtained.

In the prior art, in order to interleave a plurality of product codes and to distribute outer-code parity data in respective rows, outer-code parity rows must be inserted in a plurality of sectors. Hence, a set of a plurality of sectors must be recorded, or two different types of sectors, i.e., sectors with and without parity data must be prepared.

According to the present invention, a rewrite can be made for each sector. Especially, since an exchange process of defective sectors can be done for respective sectors, the reserve sector size required for the exchange process can be reduced. Also, since the area, use of which is disabled due to defects, can be reduced, the disk use efficiency can be improved. Also, as sector identification data (ID) to be assigned to respective sectors can be recorded at equal intervals in recording data, the ID can be easily detected and reproduced.

In the invention described above, for example, n = 2 is set. In correspondence with the SOBU size, "2 ECC blocks = 32 physical sectors" is set as a basic unit, and all data in 32 physical sectors is assigned to 2 ECC blocks in the basic unit to assure full

compatibility with the stream standards. Also, the
recording/reproduction process of a data recording
apparatus complying with the stream standards can be
simplified.

5   <2> Furthermore, a sixth data unit is defined as
follows.

A sixth data unit (e.g., byte unit) obtained by
further segmenting the fourth data unit (row) is
defined. Since "fifth data unit = PO for one row" has

10 already been defined, "sixth data unit = recording
interleave unit across rows" is defined to avoid
confusion.

The information recording medium of the present
invention comprises a physical sector area where sixth

15 data units selected in turn from different fourth
data units are recorded. The information recording
apparatus and method of the present invention select
sixth data units in turn from different fourth data
units, and record them on the physical sector area of

20 the information recording medium. The information
reproduction apparatus and method of the present
invention reproduce the physical sector area on which
sixth data units selected in turn from different fourth
data units are recorded.

25   The relationship between the aforementioned data
units is as follows.

fourth data unit ⊃ sixth data unit

(row including PI) (byte unit)

The point of the aforementioned invention is as follows.

Errors can be distributed by recording interleave (zigzag recording) among rows in a single physical

5 sector.

The effects of the present invention are as follows.

Conventionally, recording is done in the same direction as inner-code data. If successive data items

10 have error correlation, a run of a plurality of bytes may readily cause errors at the same time, and it is highly likely to disable correction of inner-code data. As a result, the error correction performance is lowered considerably compared to a case wherein random

15 errors are assumed. When the entire product code is obliquely recorded to distribute errors, a plurality of sectors may simultaneously cause errors.

The error characteristics of reproduced data have error correlation in successively recorded data items

20 due to the influence of dust or the like. If error correlation is present, successive errors readily occur compared to a case wherein it is assumed that errors occur randomly. In order to distribute errors that occur successively to different inner-code data,

25 the recording direction is set in a zigzag pattern

with respect to the direction of inner-code data.
As a result, since the number of correctable inner-code
data items increases, the error correction performance
can be improved. Since the zigzag pattern of the
5   recording direction is limited to the range of one
sector, successive errors never spread to a plurality
of sectors. Hence, a plurality of sectors can be
avoided from causing errors due to serious errors.

<3> Moreover, physical sector information and
10   logical sector information are defined as follows.

User information recorded in a physical sector
that forms the first data unit is defined as physical
sector information. The minimum unit of user
information transferred in a data recording apparatus
15   or data reproduction apparatus, or the minimum unit of
user information transferred in the data recording
apparatus or between the data reproduction apparatus
and external device is defined as logical sector
information.

20   The information recording medium of the present
invention comprises a physical sector area that records
data which is generated so that the contents of the
physical sector information match those of the logical
sector information. The information recording
25   apparatus of the present invention generates and
records data so that the contents of the physical
sector information match those of the logical sector

information. The information reproduction apparatus
and method of the present invention reproduce the
physical sector area that records data which is
generated so that the contents of the physical sector
information match those of the logical sector
information. In this manner, the physical sector
information can match the logical sector information.

The effects of the aforementioned invention are as
follows.

1) Data access can be made for respective logical
sectors. When the error rate of a reproduced signal
from the optical disk is low, and error correction of
respective rows in the physical sector can be made
using only PI information, error-free (accurate)
physical sector information can be read out without
using PO information. Hence, when ECC blocks are
formed so that logical sector information matches
physical sector information as in the present
invention, if the error rate of a reproduced signal
from the optical disk is low, one logical sector
information can be read out by only reproducing one
physical sector data from the optical disk without
using any PO information, thus allowing very easy data
access.

In the present invention, a data ID containing
sector address information is arranged at the
head position in each physical sector data item.

In general, this data ID is used to access data
recorded on the optical disk. According to the present
invention, since the contents of the logical sector
information match those of the physical sector

5   information, logical sector information can be recorded
in this data ID. Hence, as logical sector address
information in physical sector data can be directly
accessed to access the logical sector position
designated by the application or logical layer,

10   the data access time can be greatly shortened.

2) According to the present invention, data
continuity can be easily assured. In the format of
the application standards, AV information and stream
information are successively recorded in the order of

15   logical sector addresses. In the present invention,
since the contents of logical sector information match
those of physical sector information, logical sector
information can be recorded in the data ID. As a
result, the order AV information and stream information

20   to be recorded or reproduced in the order logical
sector addresses are arranged matches the order of
physical sector addresses, which is set in accordance
with the order physical sectors are arranged on the
optical disk. Consequently, an unnecessary access

25   process (track jump process) upon successively
recording or reproducing AV information and stream
information on/from the optical disk can be greatly

reduced, and continuity of AV information and stream information upon recording or reproduction can be easily assured.

3) According to the present invention, a defect process can be easily done for respective sectors.

In the prior art, when a plurality of product codes is generated in an integer number of sectors and the codes are interleaved, data of a plurality of sectors is mixed together upon recording. Hence, if successive burst errors have occurred due to defects, errors may be simultaneously produced in a plurality of sectors. Normally, since the presence/absence of errors is finally checked for each sector, many sectors readily become defective at the same time. Also, since logical addresses are nonuniformly recorded, recorded data cannot be efficiently searched.

According to the present invention, when uncorrectable errors have occurred due to defects, the residual errors can be prevented from spreading after correction. As a result, the number of sectors that contain errors can be minimized. When a specific sector is searched for while reproducing data, the target position can be easily found due to continuity of sector numbers.

<4> Furthermore, the information recording medium of the present invention comprises a physical sector area that records data which is generated, so that the

arrangement of at least some data in at least one of
a plurality of ECC blocks matches the contents of
logical sector information. The information recording
apparatus and method of the present invention generate

5   and record data so that the arrangement of at least
some data in at least one of a plurality of ECC blocks
matches the contents of the logical sector information.
The information reproduction apparatus and method of
the present invention reproduce the physical sector

10   area that records data which is generated, so that the
arrangement of at least some data in at least one of
a plurality of ECC blocks matches the contents of the
logical sector information. In this way, the contents
of the logical sector information match the data

15   arrangement in an ECC block.

The effect of the aforementioned invention is as
follows.

Processes until formation of ECC blocks for
logical sector information, which is to be transferred

20   in a data recording apparatus or between a data
reproduction apparatus and external device, match those
until formation of ECC blocks in the existing DVD.
Hence, some of the ECC block generation processes
(generation of PI and PO, and the like) and error

25   correction processes in a reproduction apparatus or
recording/reproduction apparatus having compatible
functions between existing DVDs and next-generation

DVDs can be used common to those used upon using an existing DVD disk, and the processing routines and circuits of the reproduction apparatus or recording/ reproduction apparatus having compatible functions between existing DVDs and next-generation DVDs can be simplified.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.